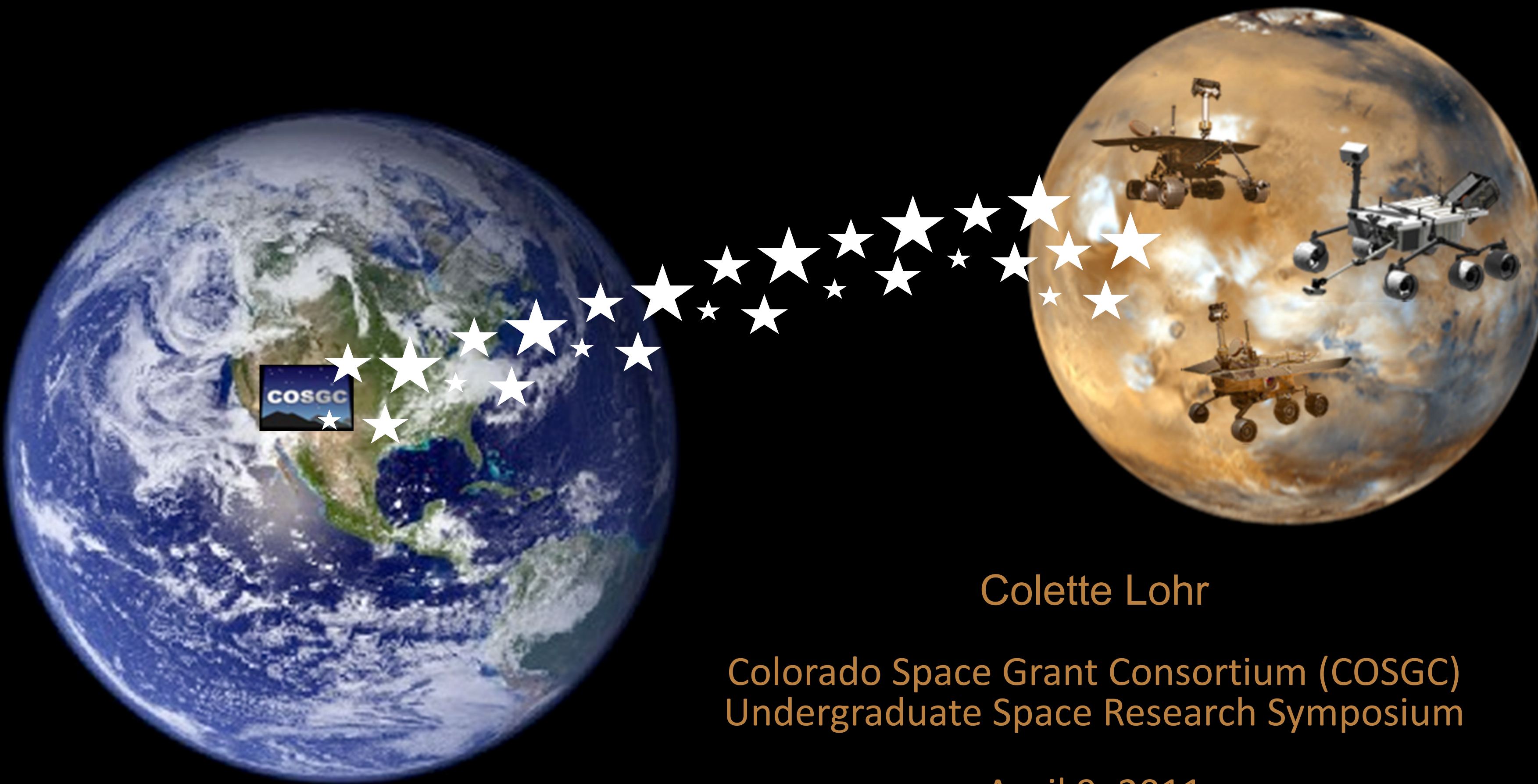
From Space Grant to Mars and Beyond



Colette Lohr

Colorado Space Grant Consortium (COSGC)
Undergraduate Space Research Symposium

April 9, 2011

COSGC Street Cred

DATA-CHASER - *Hitchhiker Class Space Shuttle Payload, STS-85*:
1995-January 1997 - member of the thermal team, power team, power team lead, integration and test team
January 1997-August 1997 – Member of the DATA-CHASER mission operations system team

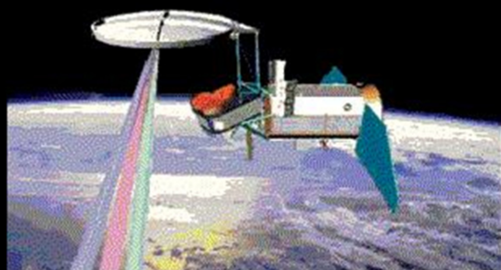
Citizen Explorer:
May 1997-May 1999 - Team Lead, Mission Operations System
May 1999-August 2000 - Software System Team Member
May 1999-May 2001 – Mission Operations Advisor
August 2000-May 2001 - Software Team Lead

Three Corner Sat:
August 2000-May 2001 - Member/Advisor Mission Operations System

Located in Pasadena, CA, JPL is a Federally (NASA)-owned Federally-Funded Research and Development Center (FFRDC), operated by the California Institute of Technology (Caltech)

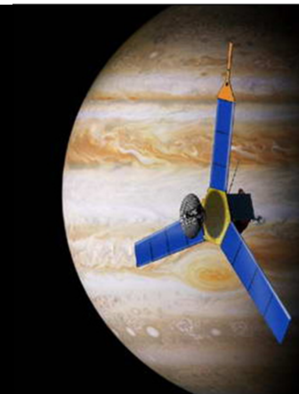
Nineteen spacecraft and ten instruments across the solar system (and beyond)

Looking ahead: Missions and instruments to be launched in the near future



Aquarius

June 2011



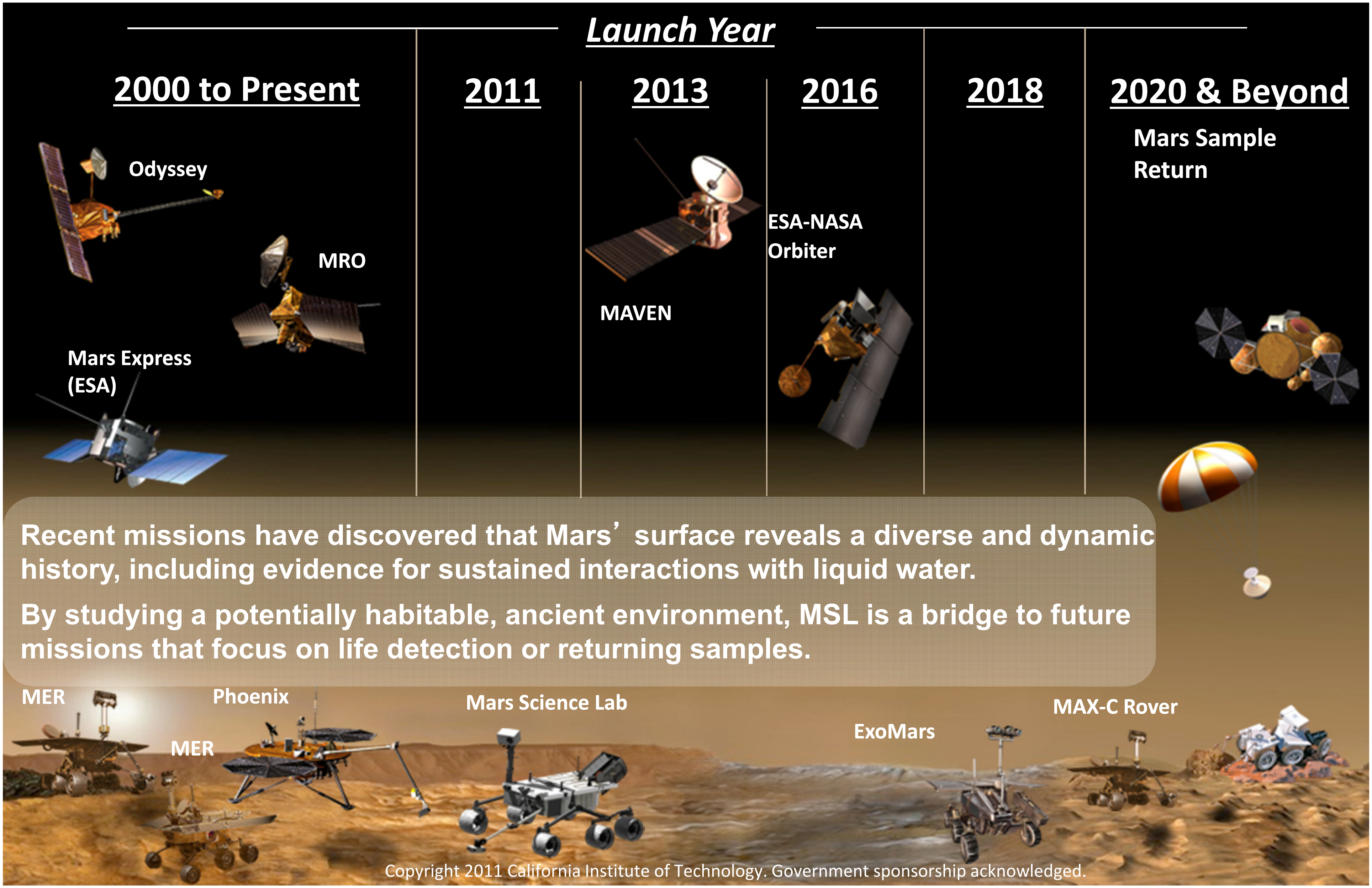
Juno
August 2011

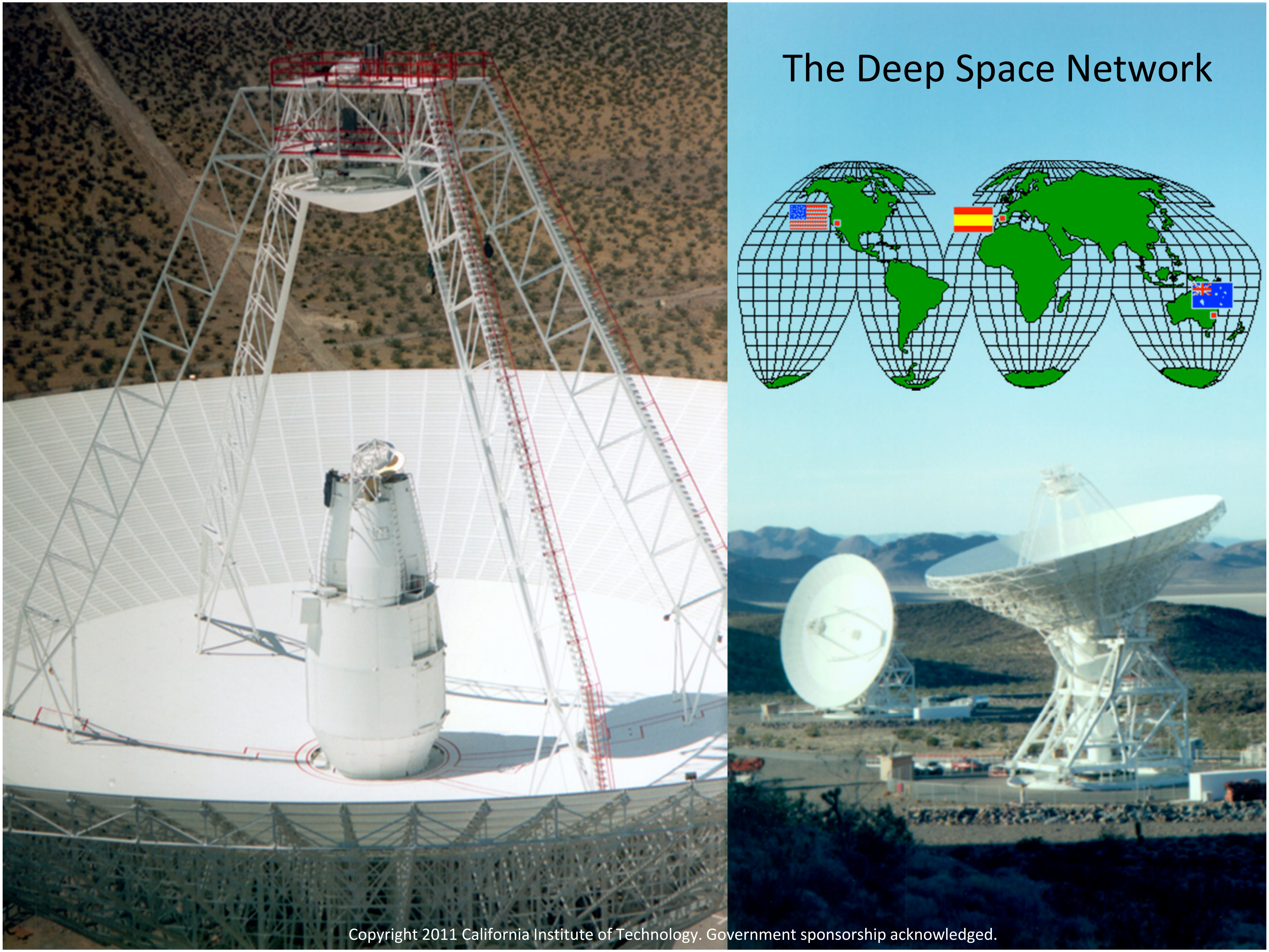
NuSTAR
February 2012

GRAIL
September 2011

Mars Science Laboratory
Launch November 2011
Landing 2012

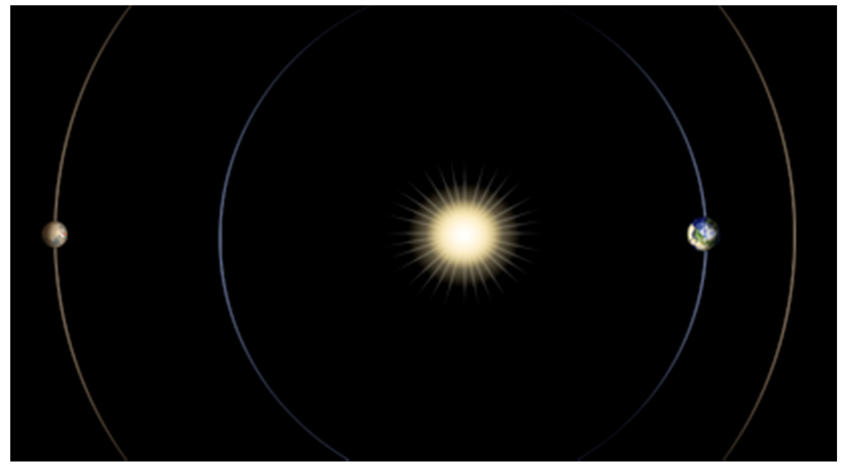
NASA’s Mars Exploration Program



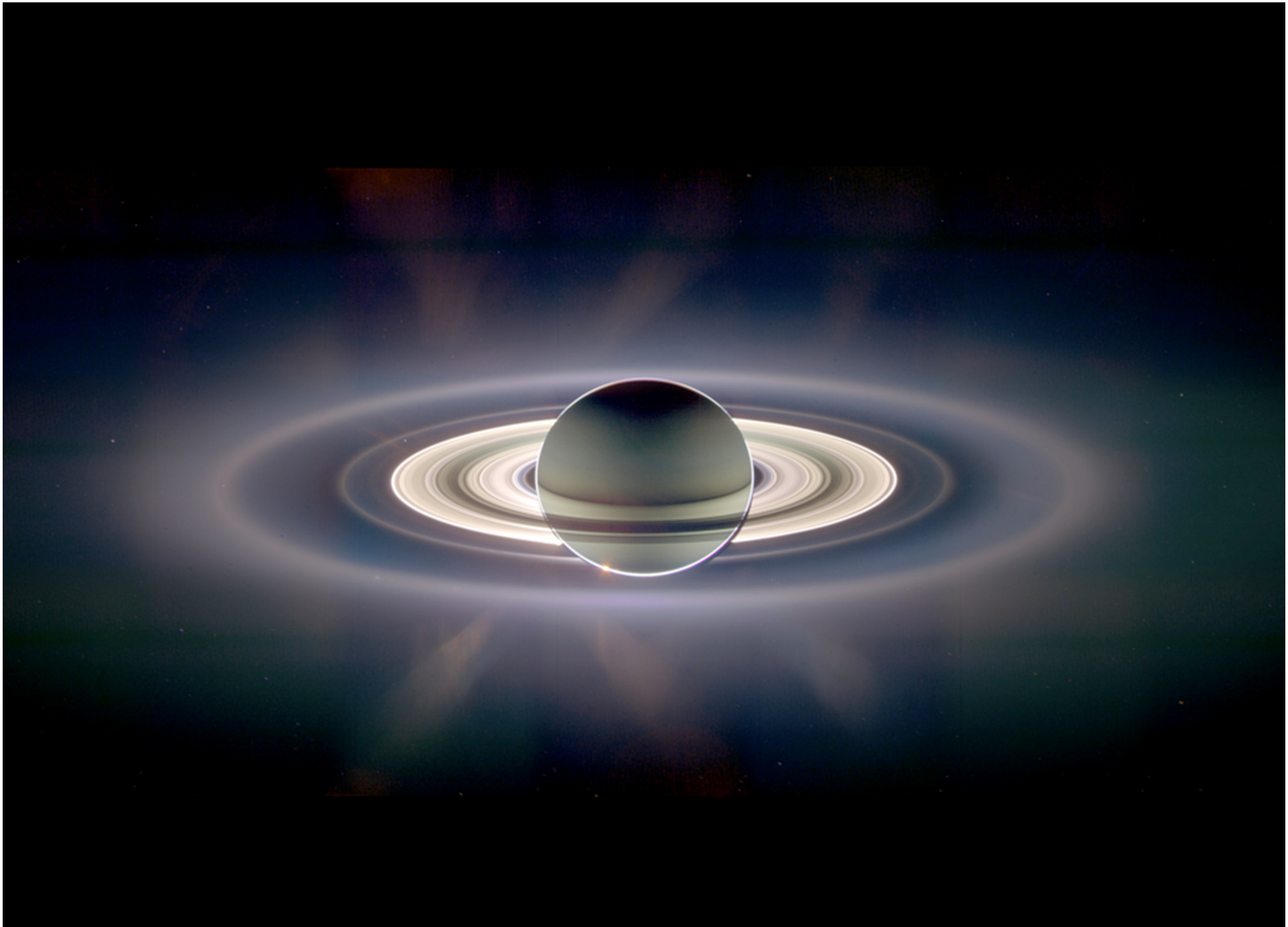

The Deep Space Network

Unique Operational Experiences of Planetary and Deep Space Missions

- Communication restrictions
  - Delayed knowledge of spacecraft state
  - Limited data volume return
  - Long light-time - It can take 10-20 minutes or longer to receive a transmission from Mars, depending on the current distance between Earth and Mars
  - Impacts of orbital mechanics - Solar conjunction impacts our ability to communicate with our spacecraft at Mars for about 2 weeks every 2 Earth years
  - The Deep Space Network is a limited resource – Multiple missions in contention



- Onboard automation
  - Execution of pre-planned command sequences
  - Response to anomalies (Fault Protection)
- Missions are scientifically unique, requiring science and engineering goals to be negotiated regularly
- Utilization of Relay Assets at Mars
- Working Mars Time



Voyager 1 launched on September 5 1977,
more than 33 years ago

Voyager 1 is flying nearly 11 billion miles from Earth, and is humanity's most distant spacecraft

It takes ~16 hours for Voyager 1's radio signals to reach Earth

The signal from Voyager 1 is so weak, that the amount of power striking the antenna at the DSN is ~20 Billion times less than the power used to operate a modern-day electronic digital watch

On March 8 2011, The spacecraft rotated 70 degrees to detect the solar wind. This was the first time the spacecraft had done any major maneuvering since 1990

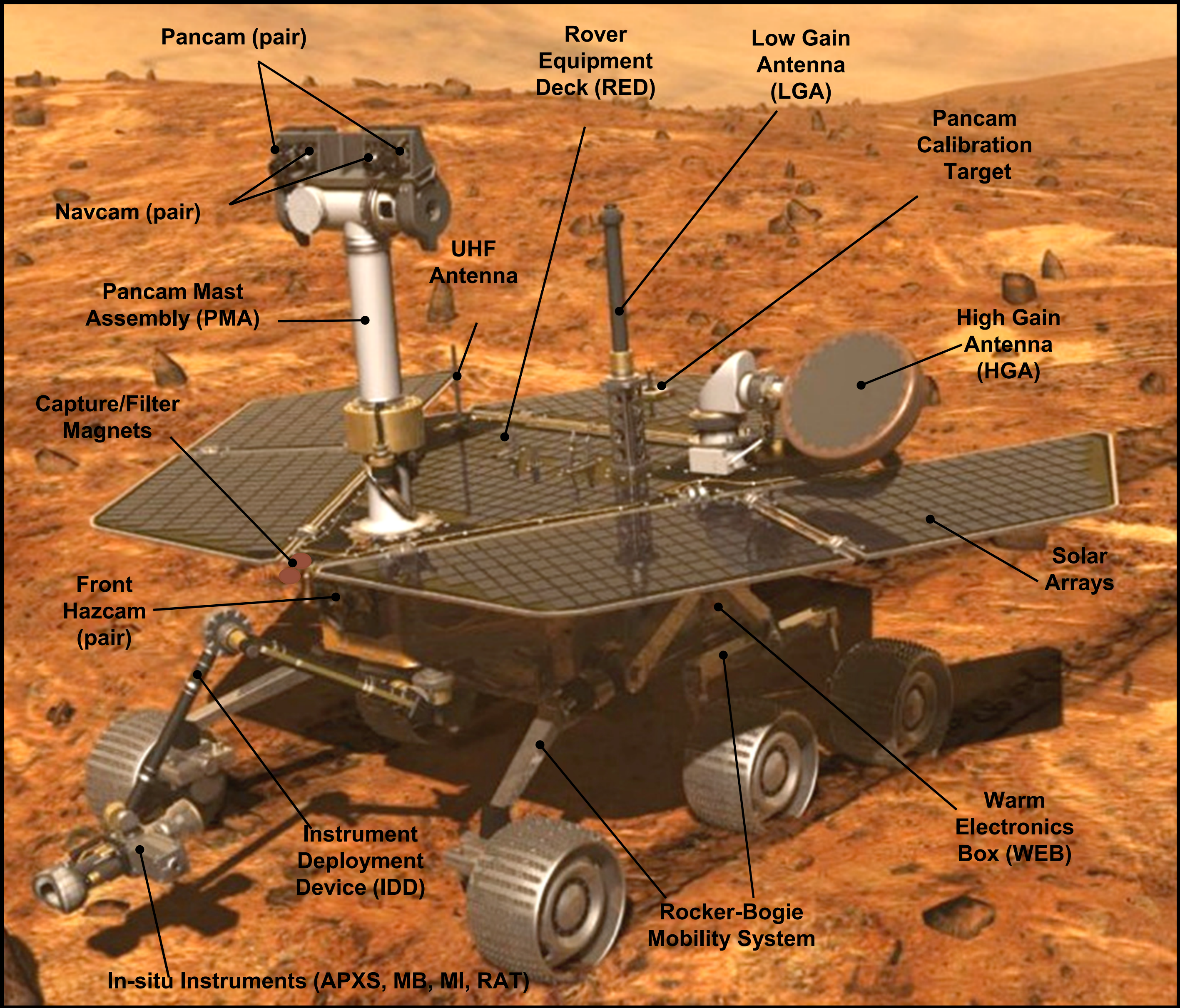
The Mars Exploration Rover Mission

- Spirit and Opportunity
  - Two mobile geologic laboratories
  - Conduct a geologic assessment of past environments on Mars at two distinct locations
    - Gusev Crater
    - Meridiani Planum
  - Expected lifetime ~90 Martian sols
  - Mission success criteria called for 600 meter drive distance, (less than half a mile)
  - The likely end of mission - insufficient power due to dust build up on the solar arrays

Key Dates:
10 Jun 2003: Spirit Launch
7 Jul 2003: Opportunity Launch
4 Jan 2004: Spirit Mars Landing (UTC)
25 Jan 2004: Opportunity Mars Landing (UTC)

Rover Deployed on Mars

- 179 kg
- 1.54 m from ground to Pancam eye level



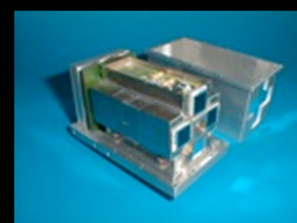
Athena Payload and Cameras

- **Pancam** – high-resolution (16°x16°) color panchromatic stereo cameras
- **Mini-TES** – a mid-infrared point spectrometer
- **Microscopic Imager** – close-up imaging of rock and "soil"
- **Mössbauer Spectrometer** – analysis of iron in rocks
- **Alpha Particle X-Ray Spectrometer** – detects elements in rocks and "soils"
- **Rock Abrasion Tool** – used to remove outer surface of rocks for analysis of non-weathered rock material
- **Magnets and calibration targets** – To collect iron containing dust and for comparison to known sources
- **Engineering cameras**
  - Navcam – wide-angle stereo cameras (45°x 45°) used for traverse planning
  - Hazcam – very-wide-angle (120°x120°) stereo cameras used for identifying potential hazards to rover driving and arm movement

Pancam

Mini-TES

MI



MB

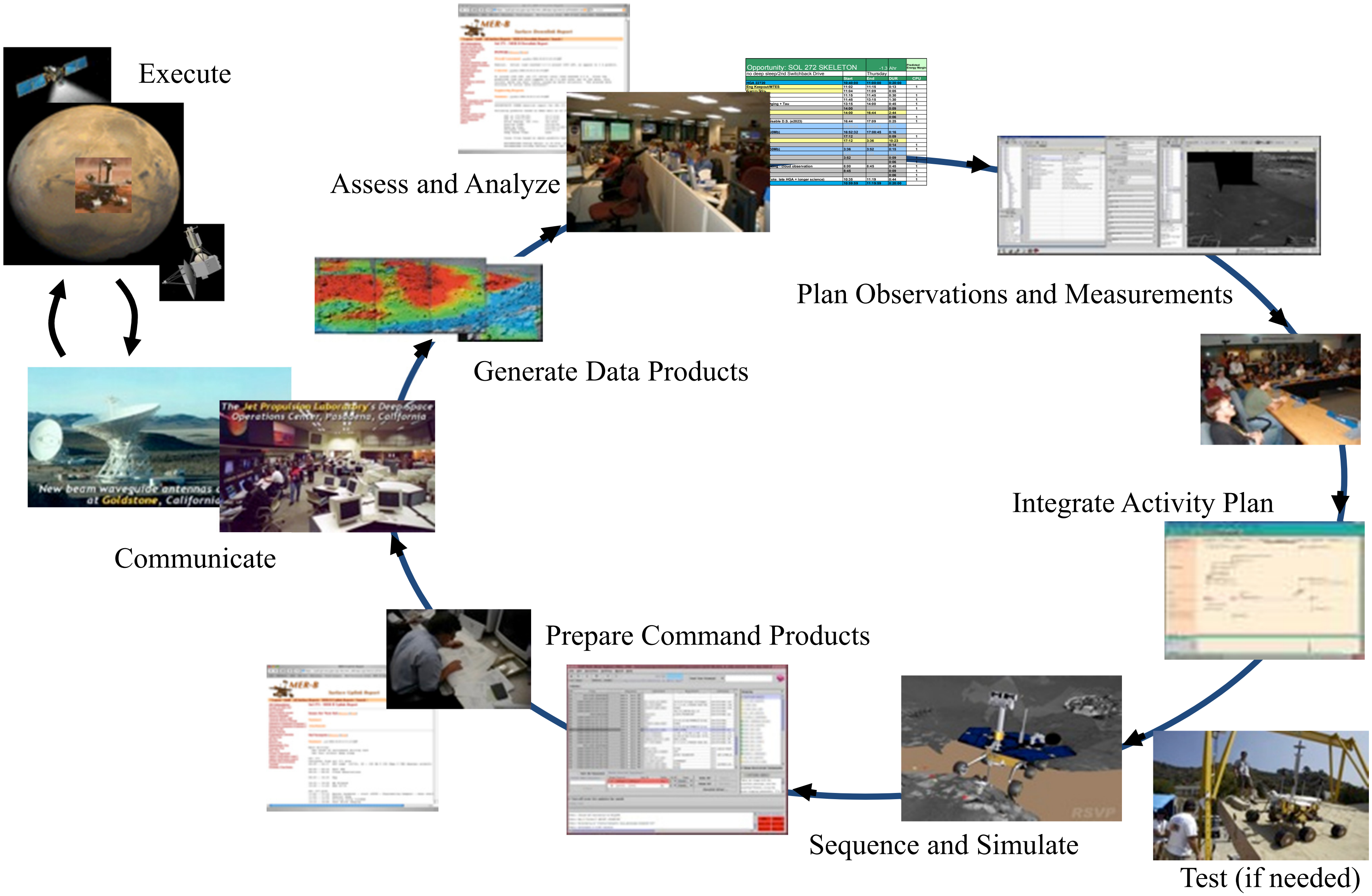
APXS

RAT

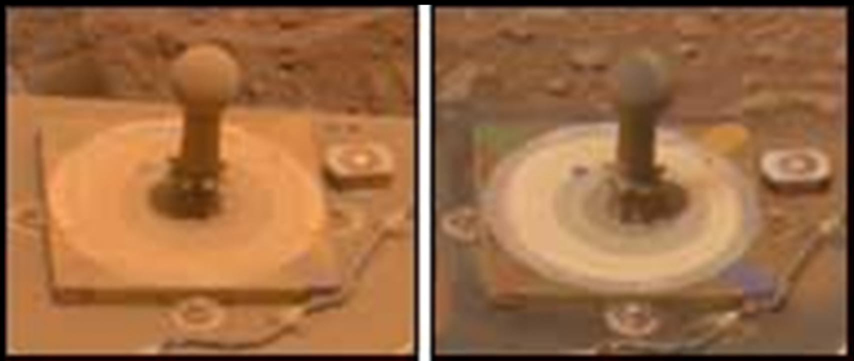
Working Mars Time

- 1 Day or “Sol” on Mars is equivalent to 24 Hours, 40 Minutes on Earth
- The work shift then starts 40 minutes later each (Earth) day
- Working Mars time Provides maximum number of work hours between when critical operations conclude for the day on Mars (when data is downlinked) and the time we uplink the next Sol’s commands the next morning
- Mars time allows key spacecraft and ground events to be tightly coordinated
  - Sol n afternoon downlink triggers uplink planning process (downlink analysis, science planning meetings, activity plan approval, command and radiation approval) which must complete in time for sol n+1 uplink
  - Spacecraft and ground activities happen at a consistent time on the Mars clock
- Personnel have clear understanding of when spacecraft events will occur
  - Easy to know what’s happening on Mars right now
- Although sustainable from a physiological perspective, working Mars time incredibly disruptive of team members' personal lives and can lead to fatigue-related symptoms

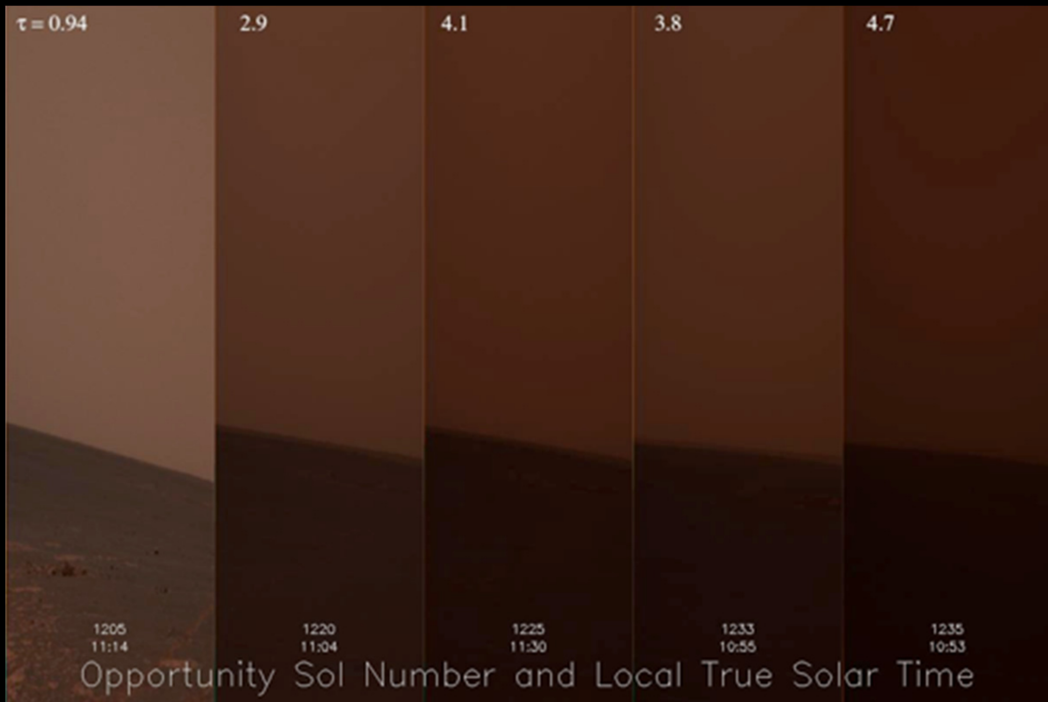
MER Surface Operations Cycle

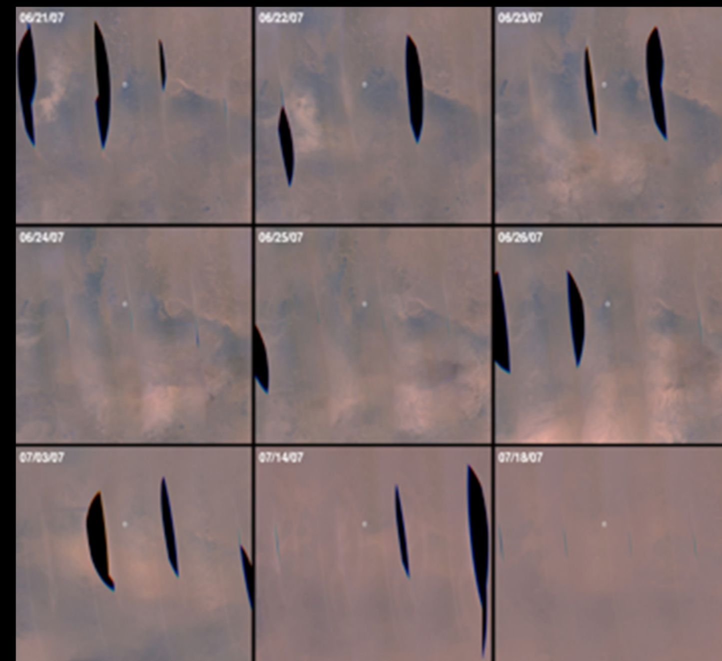


- Dust accumulation on the rovers' solar arrays was expected to significantly limit their performance soon after completion of the 90-sol prime mission
- Wind gusts effectively swept dust off the solar arrays, increasing power intake
- Both rovers have experienced "dust cleaning" events, significantly extending the life of the mission



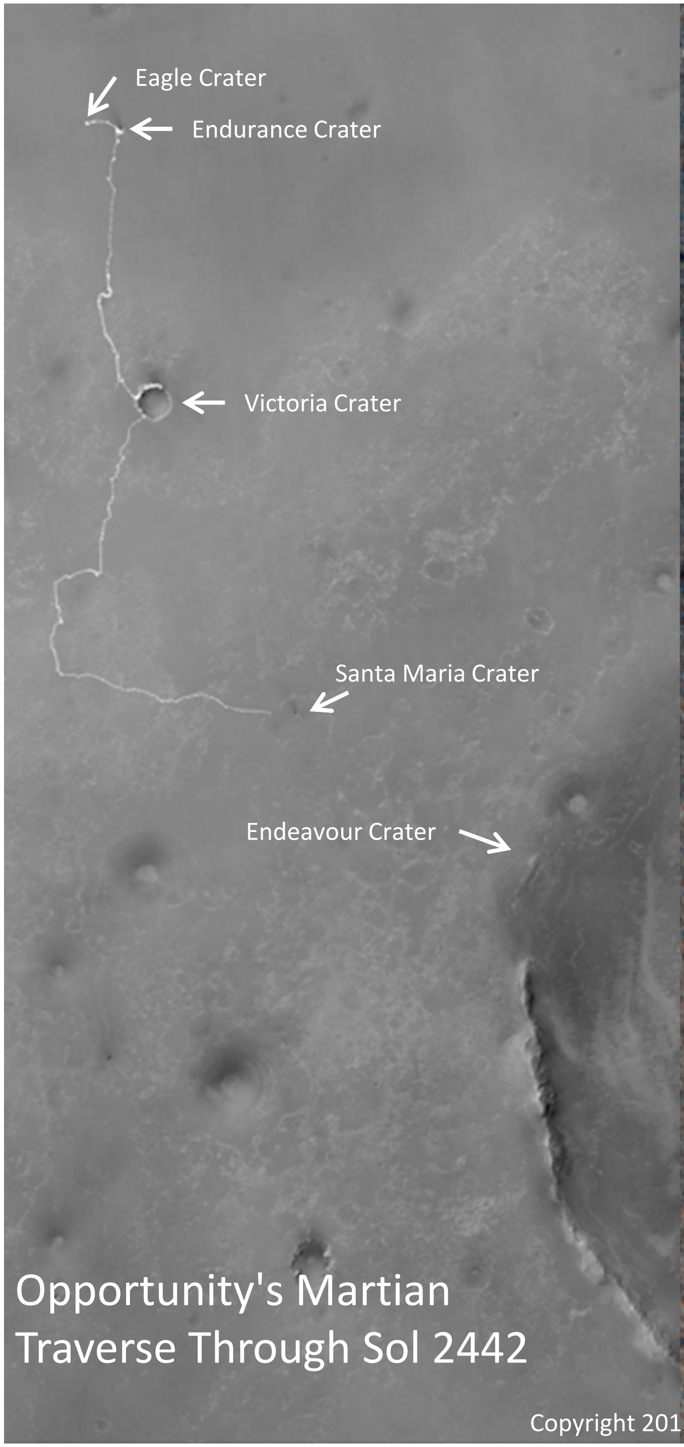
Spirit Calibration target sol 426 and 433





- Dust storms on Mars darkened skies over both Spirit and Opportunity in June, 2007
- The rovers rely on electricity that their solar panels generate from sunlight
- Dust can degrade the performance of our cameras and science instruments
- Both rovers were commanded into very low power usage configurations
- After about six weeks of hunkering down during the raging dust storms, both of the rovers resumed normal operation

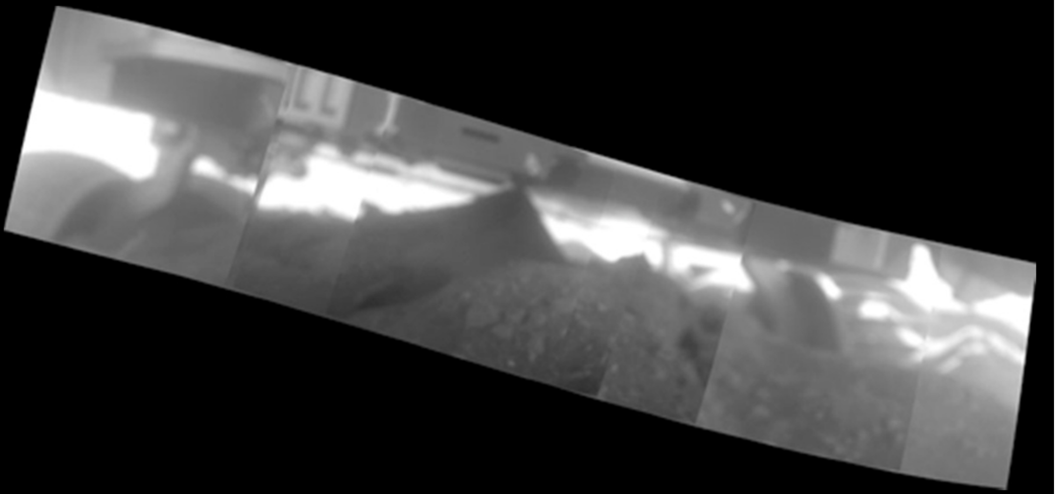
Where are they now?


Eagle Crater
Endurance Crater
Victoria Crater
Santa Maria Crater
Endeavour Crater
Opportunity's Martian
Traverse Through Sol 2442


Opportunity at Santa Maria Crater, image
taken via HiRISE instrument aboard the
Mars Reconnaissance Orbiter (MRO)

- April 2009, the Spirit team was working to diagnose a series of reboots and amnesia events, in which Spirit unexpectedly fails to record data into the flash memory
  - Root cause remains undetermined, the team resumed nominal operations while the investigation continued

- May 2009, Spirit began to become embedded in soft soil, embedding became deep enough that there was concern that the rover belly could be in contact with rocks beneath the rover
  - An additional challenge, Spirit's right front wheel had stopped operating in March 2006



- An extensive test campaign began to aid the extrication effort
- The testbed setup included a mixture of powdered clay and diatomaceous earth to simulate the physical properties of the soil we encountered on Mars, as well as placement of a rock under the rover belly

FREE SPIRIT

- November 2009, While drive minimal progress had been made, Spirit experienced a stall in the right rear wheel
- Diagnostics on the wheel stall were not promising, and the wheel remained immobile
- However, some motion was observed on the right front wheel, though this was inconsistent
- Final drives in preparation for the Martian winter were performed using Spirit's 4 remaining working wheels, and while some small progress was observed, Spirit was unable to achieve a favorable tilt
- Without a favorable tilt for the winter, Spirit, as expected, went into a low-power hibernation mode

Spirit has not communicated since March 22, 2010.

On July 26, 2010, the team began using a paging technique called "sweep and beep" in an effort to communicate with Spirit.

If the rover has enough power to wake up, the rover would respond with a “beep”

During the Martian winter with most heaters turned off, Spirit experienced colder internal temperatures than in any of its three previous winters on Mars

The cold could have damaged any of several electronic components that, if damaged, would prevent reestablishing communication with Spirit

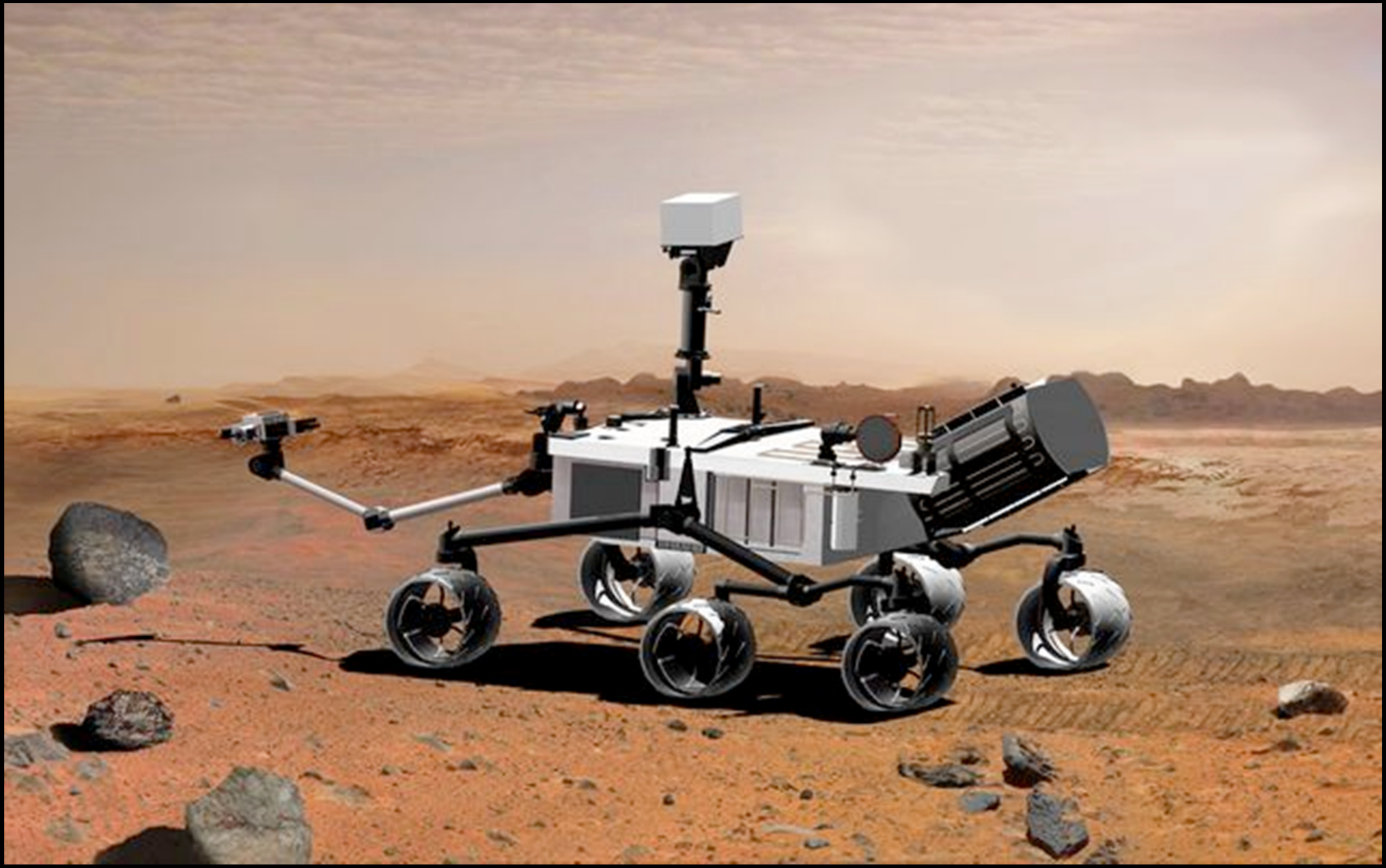
The time has passed where the team would expect to hear from Spirit due to the seasonal increase in solar energy

The team is currently pursuing communication strategies designed to address more than one problem on the rover, including hailing from the Mars orbiters for extended periods of time and attempting to use the backup transmitter on the rover

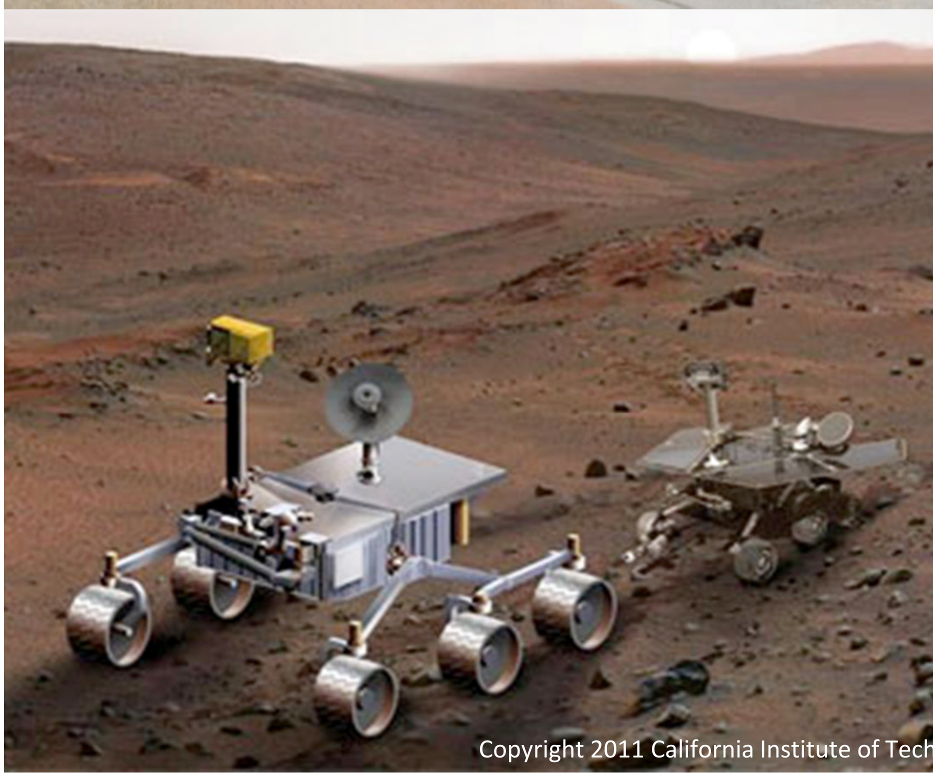
Milestones

- Since landing, the rovers have:
  - Enabled significant scientific research in Martian geology, atmospheric science, mineralogy, geochemistry, rock/soil physical properties, Astronomy, and more
  - Provided evidence contributing to the Martian water history story
    - The MER science team has amassed an enormous amount of data and the resulting discoveries cannot be adequately addressed in this presentation
  - Lasted more than 27 times longer than the expected 90 Sol mission! (and counting!)
  - Been operating on the surface for more than 7 Earth years and 3.5 Martian years!
  - Opportunity has survived 4 Martian winters!
    - Spirit has survived 3 Martian winters + (TBD)
  - Survived a potentially fatal dust storm!
  - Taken a combined total of more than 270,000 images!
  - Driven more than a combined total of over 34 kilometers! (more than 21 miles!)

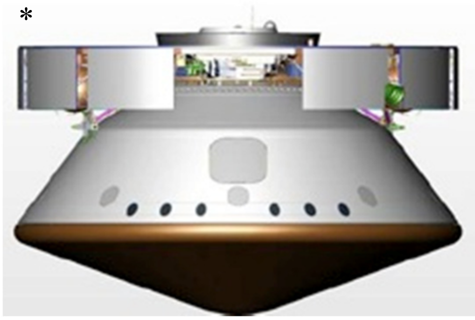
Mars Science Laboratory





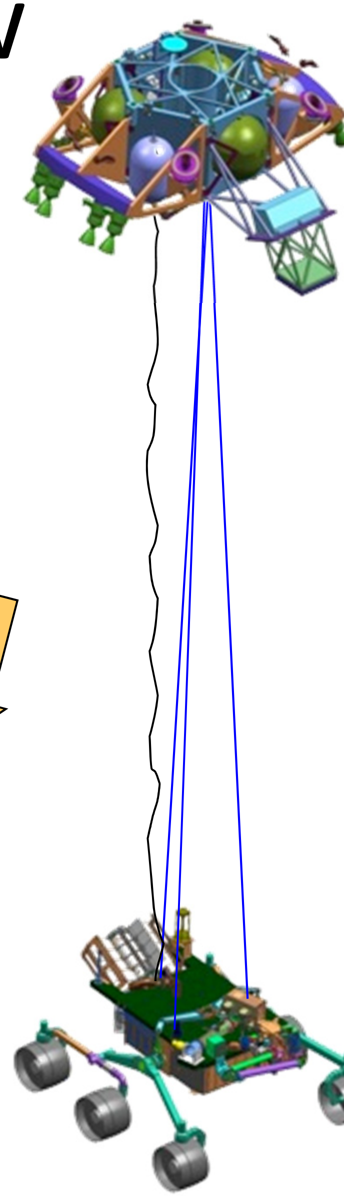



MSL Mission Overview


*

CRUISE/APPROACH
- 9-10 month cruise
- Spinning cruise stage
- Arrive N. hemisphere summer

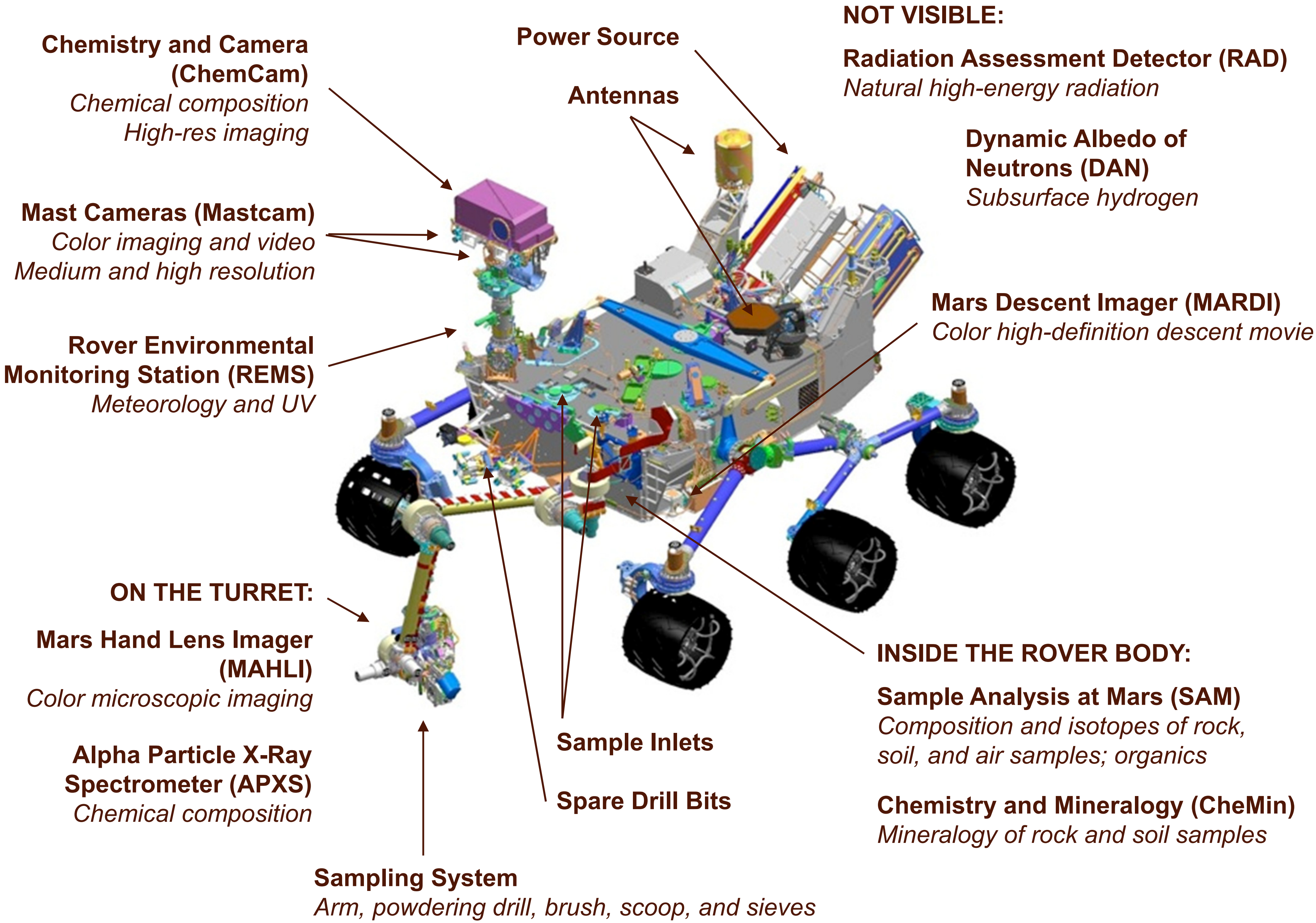
ENTRY, DESCENT, LANDING
- Guided entry and controlled, powered “sky crane” descent
- 20×25-km landing ellipse
- Discovery responsive for landing sites ±30º latitude, <0 km elevation
- ~1000-kg landed mass

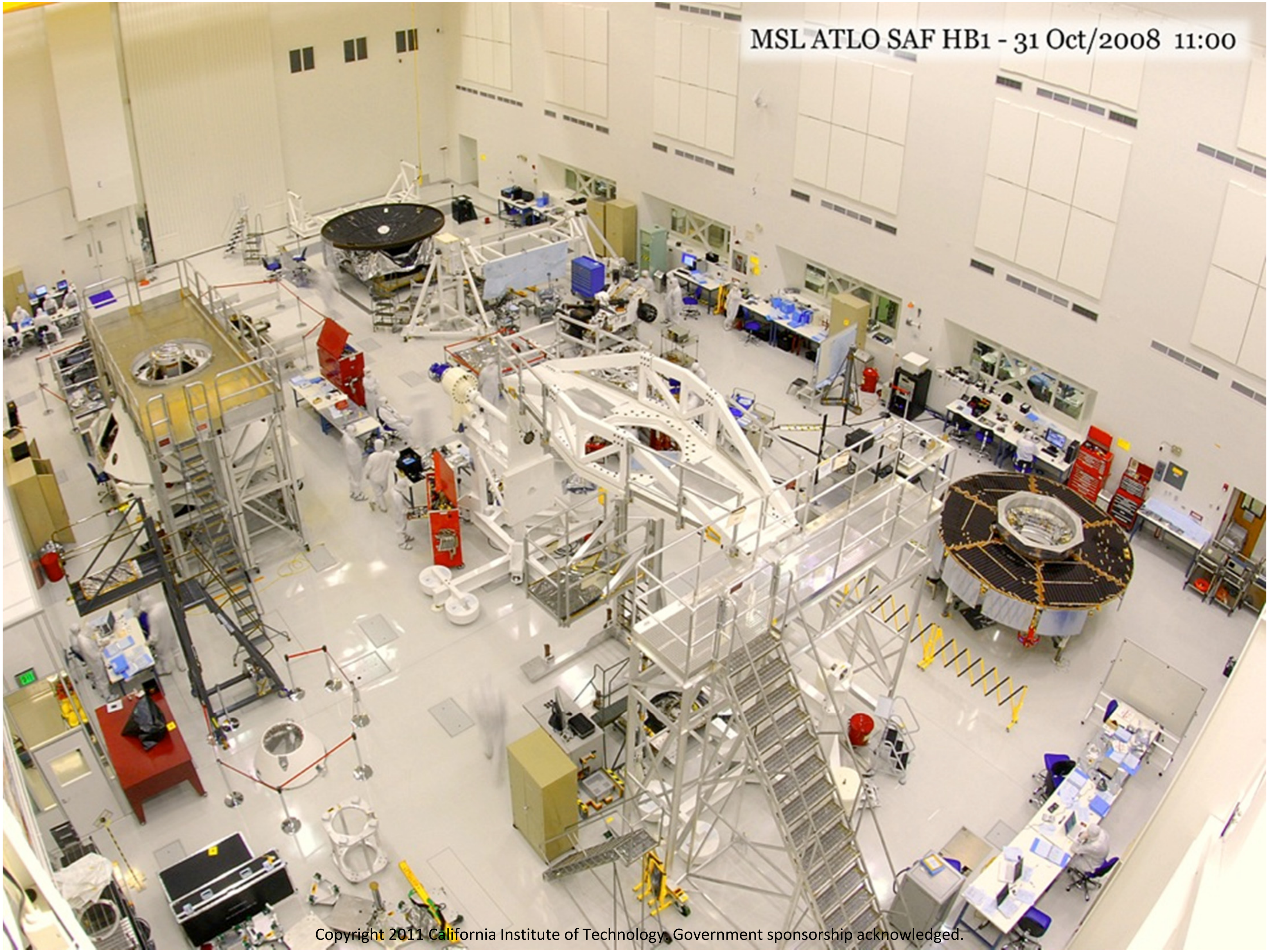

*

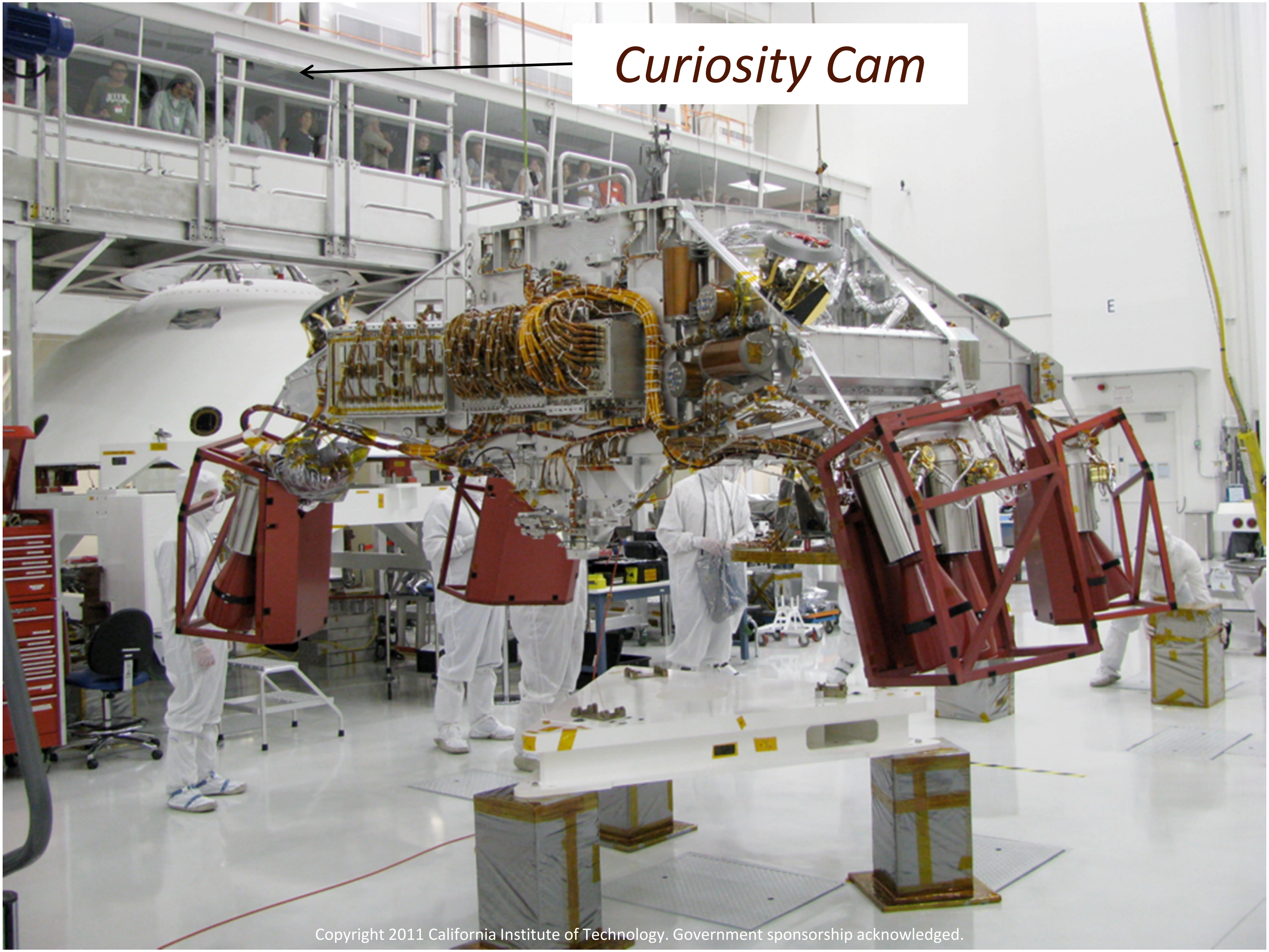
LAUNCH
- Nov. 2011
- Atlas V (541)

SURFACE MISSION
- Prime mission is one Mars year
- Latitude-independent and long-lived power source
- 20-km range
- 85 kg of science payload
- Acquire and analyze samples of rock, soil, and atmosphere
- Large rover, high clearance; greater mobility than MPF, MER

* Artist’s Renderings


Chemistry and Camera (ChemCam)
Chemical composition
High-res imaging
Power Source
Antennas
NOT VISIBLE:
Radiation Assessment Detector (RAD)
Natural high-energy radiation
Dynamic Albedo of Neutrons (DAN)
Subsurface hydrogen
Mast Cameras (Mastcam)
Color imaging and video
Medium and high resolution
Mars Descent Imager (MARDI)
Color high-definition descent movie
Rover Environmental Monitoring Station (REMS)
Meteorology and UV
ON THE TURRET:
Mars Hand Lens Imager (MAHLI)
Color microscopic imaging
Alpha Particle X-Ray Spectrometer (APXS)
Chemical composition
Sample Inlets
Spare Drill Bits
INSIDE THE ROVER BODY:
Sample Analysis at Mars (SAM)
Composition and isotopes of rock, soil, and air samples; organics
Chemistry and Mineralogy (CheMin)
Mineralogy of rock and soil samples
Sampling System
Arm, powdering drill, brush, scoop, and sieves


MSL ATLO SAF HB1 - 31 Oct/2008 11:00

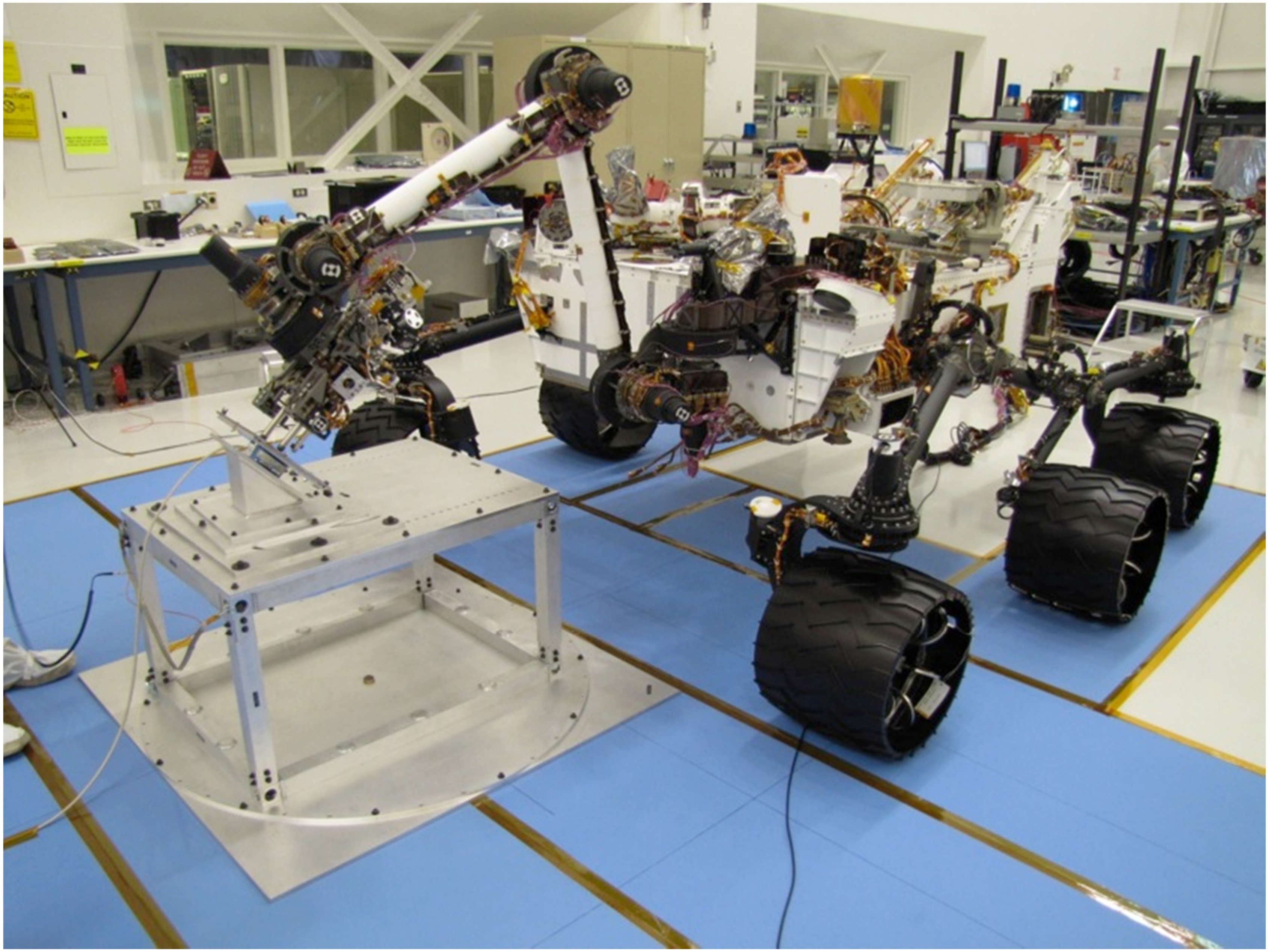

Curiosity Cam

Rover Mobility Installation

Robotic Arm Installation

Rover Drive Testing

Rover Arm Preload Testing



Alumni Postcards from JPL

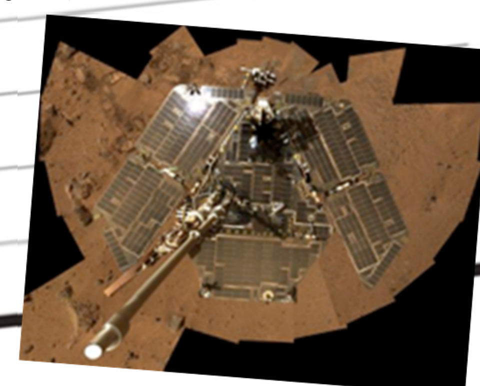
PASADENA
91109
CA

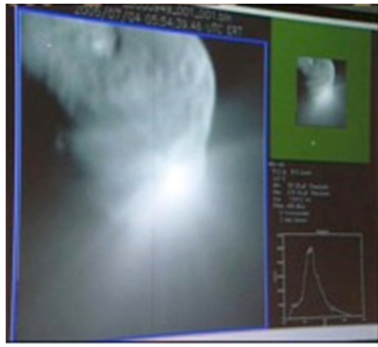
FREE
SPIRIT

Dear COSGC,
I am Mike Seibert and I a Mission Manager on the **Mars Exploration Rover Project**. I have Worked on the MER Project since joining the Lab and have held a number of roles including Ground Data System analyst, Sequence Integration Engineer, Tactical Uplink Lead, Weekend Flight Director, and was a key member of the Spirit Extrication Testing effort.

I also helped to found the Phaeton Early Career Hire Development Program.

Colorado Space Grant Consortium





Dear COSGC,

I am Jennifer Rocca. My first spacecraft at JPL, was GRACE. I was the instrument systems engineer, lived in Germany for two years, and spent a frigid February-March launch campaign in Plesetsk as the lone woman on the launch team.

On Deep Impact, I was the Independent Internal Verification & Validation Lead, Mission Scenario Test Lead, Launch Phase Lead, Launch Flight Director, Encounter Approach Phase Lead, Encounter Flight Director, Hibernation Phase Lead & Flight Director. Whew. Never worked harder in my life!

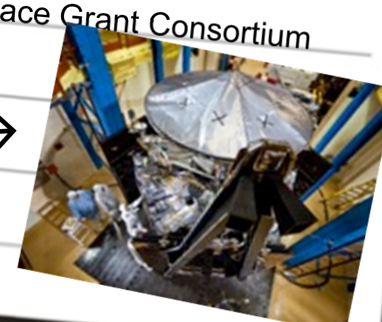
On Dawn, I was the Launch Phase Lead (and had my first baby, Lorelei Elizabeth Rocca) just days after the first launch opportunity was scrubbed. My launch didn't slip!

PASADENA
91109
CA

My current project is **Juno**, where I am the Project Verification & Validation Lead (and new Mommy of Matheson Gray Rocca) on the Project Systems Engineering Team. We launch in August! Wish you were here!! Go Buffs!

Colorado Space Grant Consortium

JUNO →

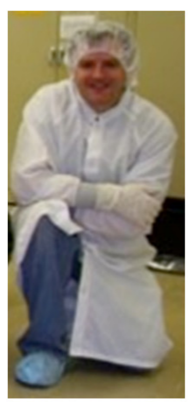


Dear COSGC, I am Peter Illsley, and I am the Assembly, Test, Launch and Operations (ATLO) Rover Integration Lead for MSL. I have worked on a the preliminary design of a number of missions such as Moonrise, Europa Orbiter, Pluto Express, and have served as the Cognizant Engineer for flight hardware on the GALEX instrument - large radiator assembly, the MER Rovers, Rover Electronics Module (REM), and MSL- Rover Primary Structure and Configuration

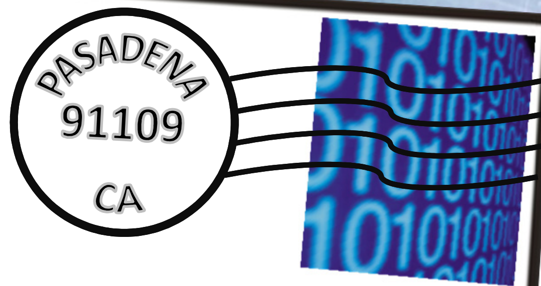
PASADENA
91109
CA

I was also an ATLO engineer for the MER REM to body integration, and was responsible for the flight rover assembly of Opportunity at JPL and at KSC prior to launch

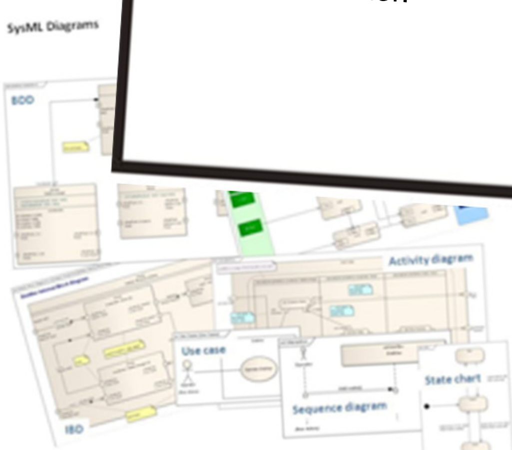
Colorado Space Grant Consortium



Dear COSGC, I am Marcus Wilkerson. Currently, I am working as the Flight System Systems Engineer and Integration & Test Lead for a a project in Phaeton call OPALS. It's an optical communication demonstration going to the ISS in 2012. The project is a good extension to the CU Aero program, as it is a real funded project that gives Early Career Hires full project life cycle experience. Rob Witoff (another CU Aero grad) is on the project with me as well. I am full time on this at the moment. I am practicing model-based system engineering (utilizing SysML) on this project, and hope to have an integrated model at the end. We begin environmental testing (thermal vac, EMI/EMC, vibe) in the winter.



Colorado Space Grant Consortium



Dear COSGC, I am *Jeannette Illsley and I have been a* Lead Maneuver Engineer during Cassini prime mission, Verification & Validation Engineer and Flight Director for the launch of **Dawn**, I have worked as an **MSL** Testbed Engineer, and am currently a Multimission Ground Systems and Services (MGSS) Operations Revitalization Systems and Training Engineer. My six years at JPL were preceded by almost 10 years working for Boeing on the F-22 program in Seattle and C-17 Flight Test at Edwards AFB.

Colorado Space Grant Consortium

Dear COSGC,

I am Jaime Catchen and I am a Cruise Planning and Sequencing Systems Engineer on MSL, transitioning from the MER Project. I got my first introduction to MER back in 2006 when I I visited JPL with a COSGC group! I though MER was the most amazing project in the whole world and I was so bummed that I missed out on being a part of this project, but I knew I had to get to JPL in hopes of being a part of something similar in the future. While on the MER Project, I have been a Tactical Activity Planner, Sequence Integration Engineer, Tactical Downlink Lead, Weekend Flight Director. and have done extensive work toward Spirit's recovery. It's amazing what can happen in 4 years! As I leave MER, in total, I will have been on the project for about 575 sols, it's not much compared to the total 2575 sols, but it's more than I ever imagined!

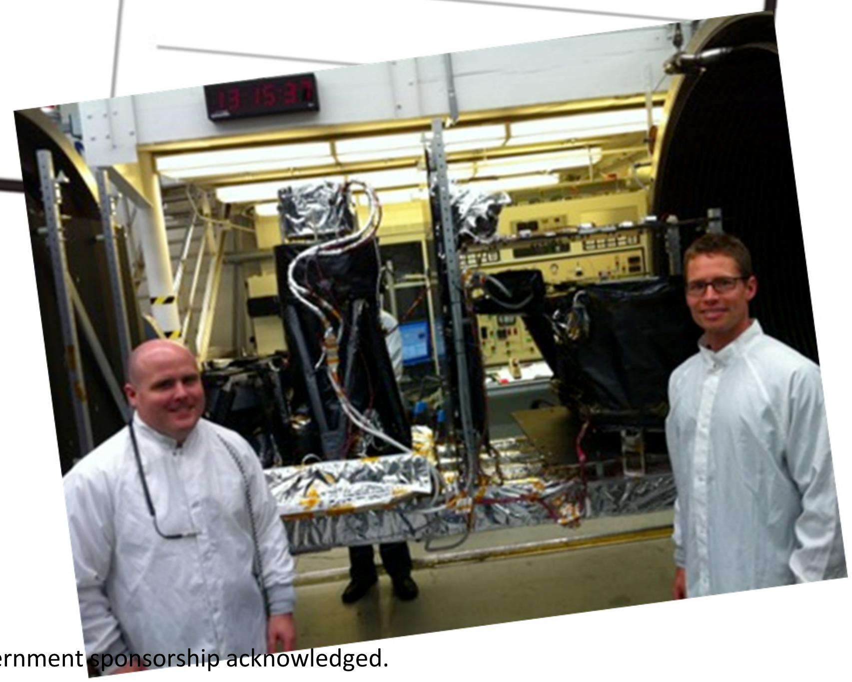
Dear COSGC,
I am Kyran Owen-Mankovich, and I am a Systems Engineer for the Multi-Mission data Processing & Control System being used by the MSL and SMAP Missions. During my 10 years at JPL I have worked mostly in the area of GDS deployment which includes deploying, adapting, and maintaining the GDS. (as well as the users). I have played a key role in the GDS team at the Cape for the launch of SIRTF, Deep Impact, and Dawn. I supported the MER project for EDL and prime Surface operations. Currently much of my time is spent supporting the MPCS deployment for MSL and working with other System Engineers to find ways to improve the system for future missions.

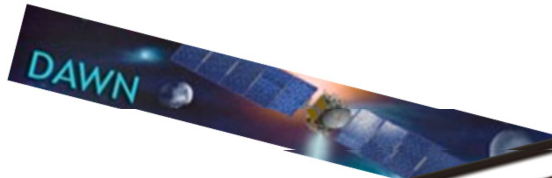
Colorado Space Grant Consortium

Dear COSGC,
I am Byron Jones, and I am the Flight Systems Engineer on the NuSTAR Project. I work on NuSTAR with fellow COSGC Alumni Jason Willis and Kathy Schimmels. Here are Jason and I with the NuSTAR instrument sitting on the thermal vacuum test ground support equipment. I have also been a Tactical Downlink Lead, Weekend Flight Director, Mission Planning Team Lead and Mission Manager for the MER Project, as well as a Surface Systems Engineer and Mission Manager on the Phoenix Mars Lander.

PASADENA
91109
CA

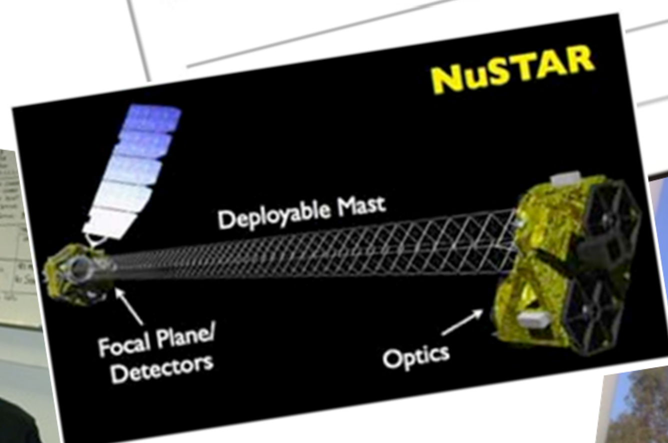
Colorado Spa Grant Consortium





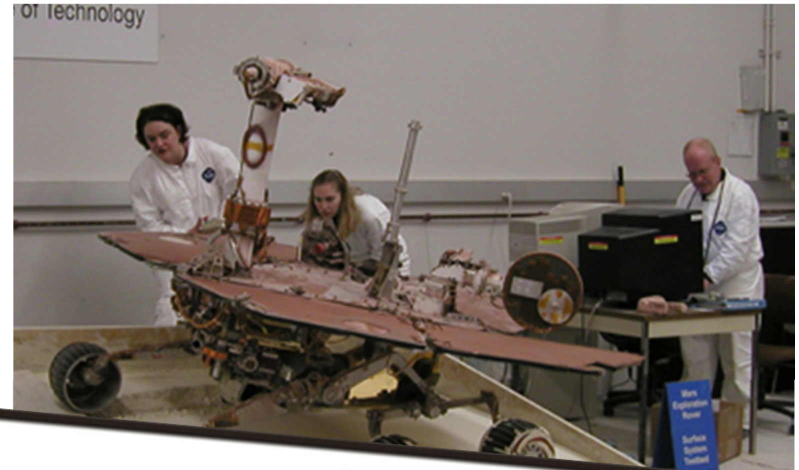
Dear COSGC,
I am **Kathy Schimmels and I worked** as a science planning & operations team chief on Galileo – right up until the mission dove into the atmosphere of Jupiter for a grand finale in 2003 (7 years!). I also worked as the Mission Operations Systems Engineer and Deputy Mission Manager / ICO Lead on Dawn for 5 years, through completion of the checkout operations. Now I'm the Mission Ops Systems Engineer on NuSTAR, which launches in Feb. 2012!

Colorado Space Grant Consortium



Dear COSGC,
I am Stephan Esterhuizen **and I Work in** Global Navigation Satellite Systems (GNSS). Some of my work Involves research using reflected GPS signals for ocean-altimetry & wind-speed retrieval among other things. The photos above show an aircraft test of this research. I still enjoy my side projects, such as Modifying the game 'operation' to run off 12V instead of 1.2V. It is quite a hit at parties!

Colorado Space Grant Consortium



Dear COSGC,
I am Colette Lohr, and I started working at the Jet Propulsion Laboratory in 1999. I began work on the Mars Exploration Rover (MER) Project in 2001, first as a software developer for the MER Ground Data System, and transitioned to MER Flight operations, serving as a Ground Data Systems Analyst, Sequence Integration Engineer, Tactical Uplink Lead, Weekend Flight Director, Spirit Extrication Test Lead, and Mission Manager.

PASADENA
91109
CA

I joined the Mars Science Laboratory Project in October 2010, and am the Integrated Planning and Execution Team's Surface Operations Lead.

Colorado Space Grant Consortium

Acknowledgements

Image Credits:
All images are credited to NASA/JPL-Caltech with additional images courtesy of the following:
Slide 2: COSGC
Slide 9: NASA/JPL/Space Science Institute
Slide 12: NASA/JPL-Caltech/Cornell
Slide 15: NASA/JPL-Caltech/Cornell
Side 16: NASA/JPL-Caltech/MSSS
Slide 17: NASA/JPL-Caltech/University of Arizona
Slide 18: NASA/JPL-Caltech/Cornell
Slide 39: http://community.sparxsystems.com/system/files/imagecache/resize/whitepaper/158/sysml-diagrams-collage.jpg

References:
Some of the content included in this presentation was derived or directly quoted from the following:

Mars Exploration Rover Press Releases:
http://marsrovers.jpl.nasa.gov/newsroom/pressreleases/index.html

A. Mishkin, “Working the Martian Night Shift: MER Surface Operations”, May 6, 2005

Postcards Content:
The content of the Alumni postcards was derived from materials collected by Colette Lohr from the alumni community (J. Catchen, S. Esterhuizen, J. Illsley, P. Illsley, B. Jones, C. Lohr, K. Owen-Mankovich, J. Rocca, K. Schimmels, M. Seibert, M. Wilkerson), some wording has been altered to fit within the format of this presentation.